



What is “Socket” Parity and is Rooftop Solar PV There Yet Without Subsidies?

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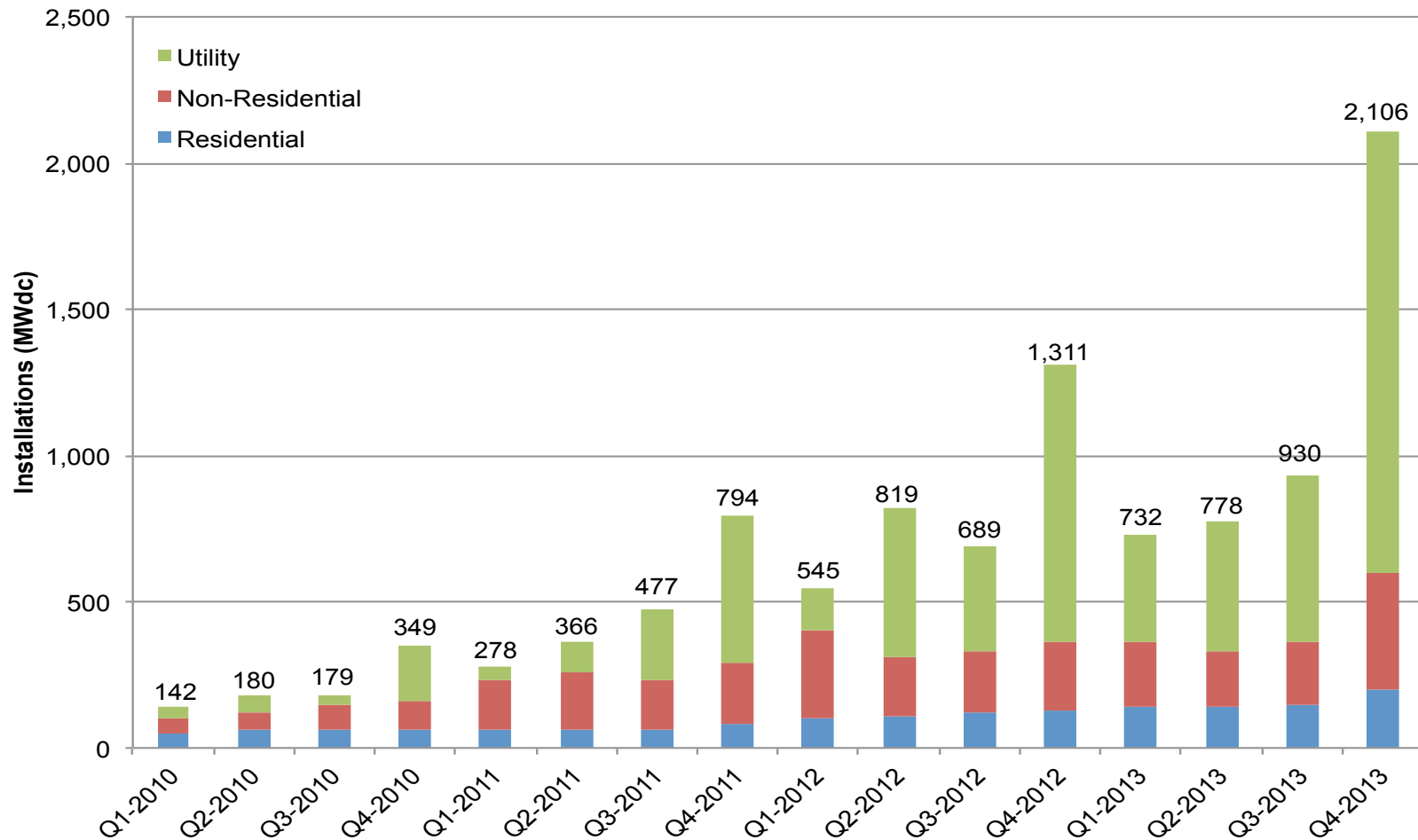


Introduction

- In recent years there have been growing efforts to support the deployment of renewable energy sources in the U.S.
 - The federal government has the solar power investment tax credit.
 - 29 state Renewable Portfolio Standards. Some include solar set-asides.



Solar PV Installations



Adapted from: Solar Energy Industries Association (2013) Solar Market Insight Report 2012 Q3. 1–17.

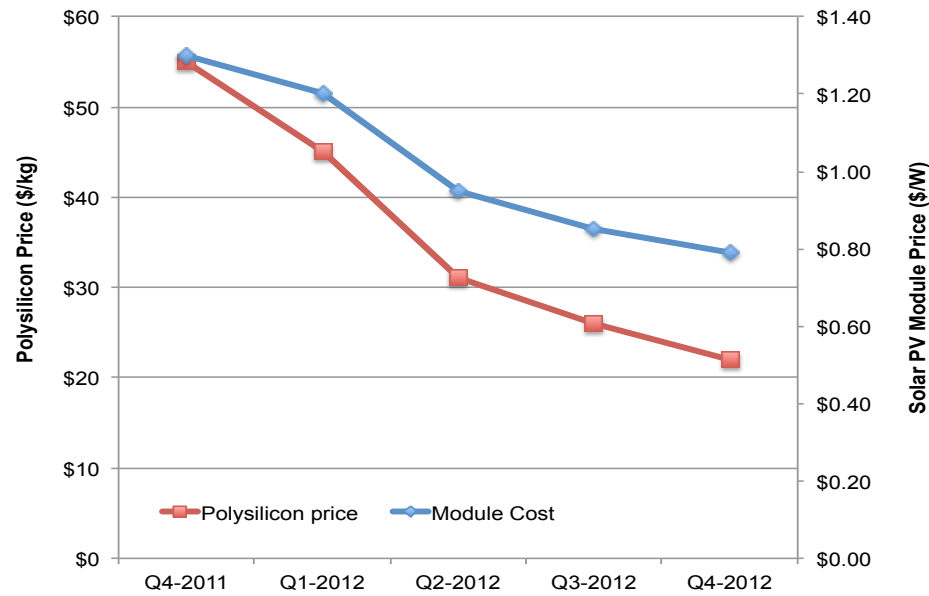


Introduction

- The costs of solar PV have also decreased in recent years, primarily as a result of the decline of polysilicon prices, which directly affects module costs.
 - Between 2008 and 2012, the reduction in polysilicon prices resulted in a 40% reduction in installed solar PV system costs

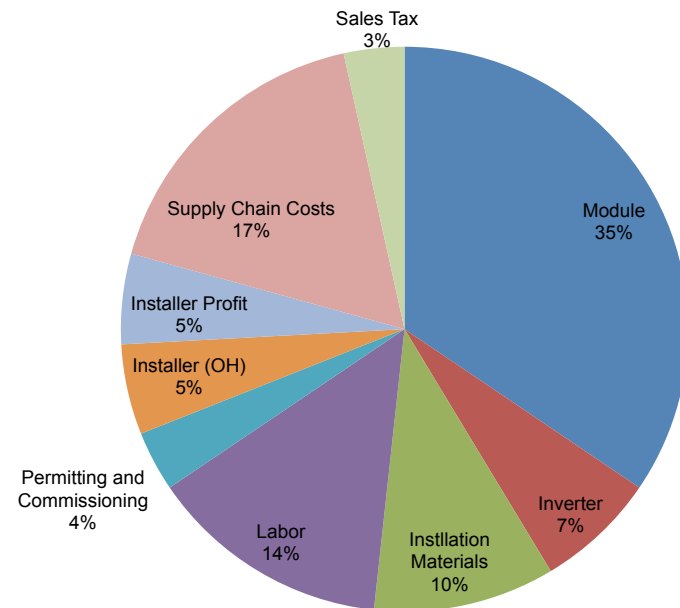


Pricing Trends



U.S. polysilicon and solar module wholesale prices, Q4 2011-Q3 2012.

Adapted from: Solar Energy Industries Association (2013) Solar Market Insight Report 2012 Q3. 1–17.



Breakdown of solar PV installation costs.

Adapted from: National Renewable Energy Laboratory (2012) Residential, Commercial, and Utility-Scale Photovoltaic System Prices in the United States.



The “Problem”

- Recent reductions in the cost of residential solar PV installations have sparked arguments that solar is either at or approaching “grid parity.”
- Existing studies have only focused on individual sites so they have failed to consider national trends and the differences in costs and electricity prices that are observed throughout the U.S.
 - They argue, however, that residential solar PV systems could continue being economically viable if congress fails to renew the ITC, which is set to expire by the end of 2016



Research Question

- In this paper we evaluate whether residential solar PV systems are in fact at socket parity without subsidies.
- We expand on the scope of previous work by modeling the economic viability of these systems in over 1,000 locations in the U.S.
- We also explore the effects of different attributes that influence the economic viability of a solar PV investment including installation costs, financing costs, and the residential retail price of electricity and escalation rate.
- We do not consider:
 - Particular rate structures that are unique to certain locations
 - Future changes to net metering structures.

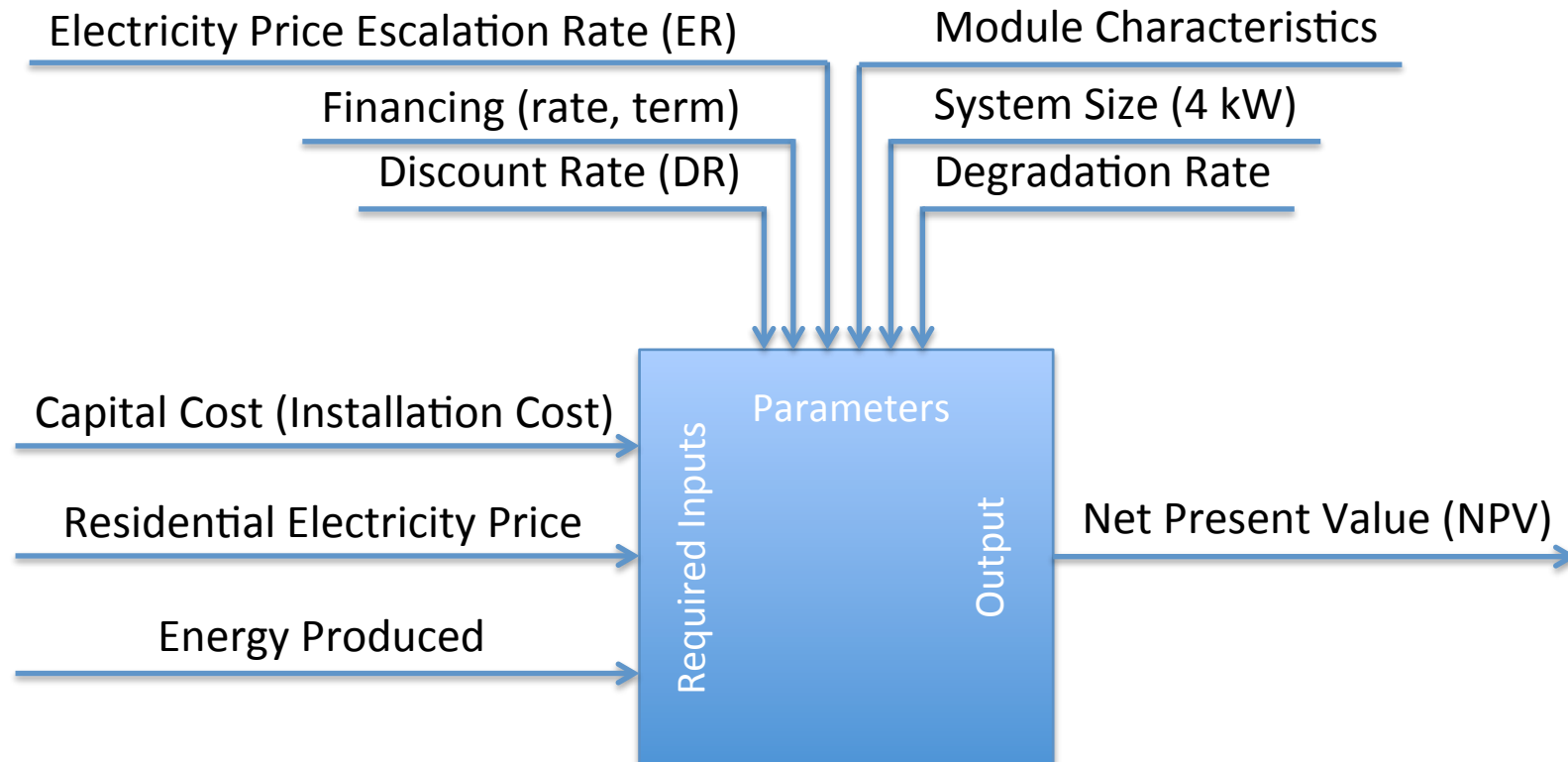


“Socket” Parity

For residential PV systems, socket parity is achieved when a technology can generate electricity at a levelized cost of electricity (LCOE) that is less than or equal to the price of purchasing electricity from the local utility.



Method





Model Parameters

- Retail Price of Electricity
 - State average residential prices [EIA]
- Escalation Rate of Electricity Prices (2-5%)
- Discount Rate (7%)
- System Details
 - 4 kW, 25 year lifetime, 0.5% degradation rate after initial 3% loss in first year¹
- Financing
 - 15-25 years, 5-8% interest rate

¹ S. Roe, “Solar Efficiency Losses Over Time.”



Installation Costs (\$/W)

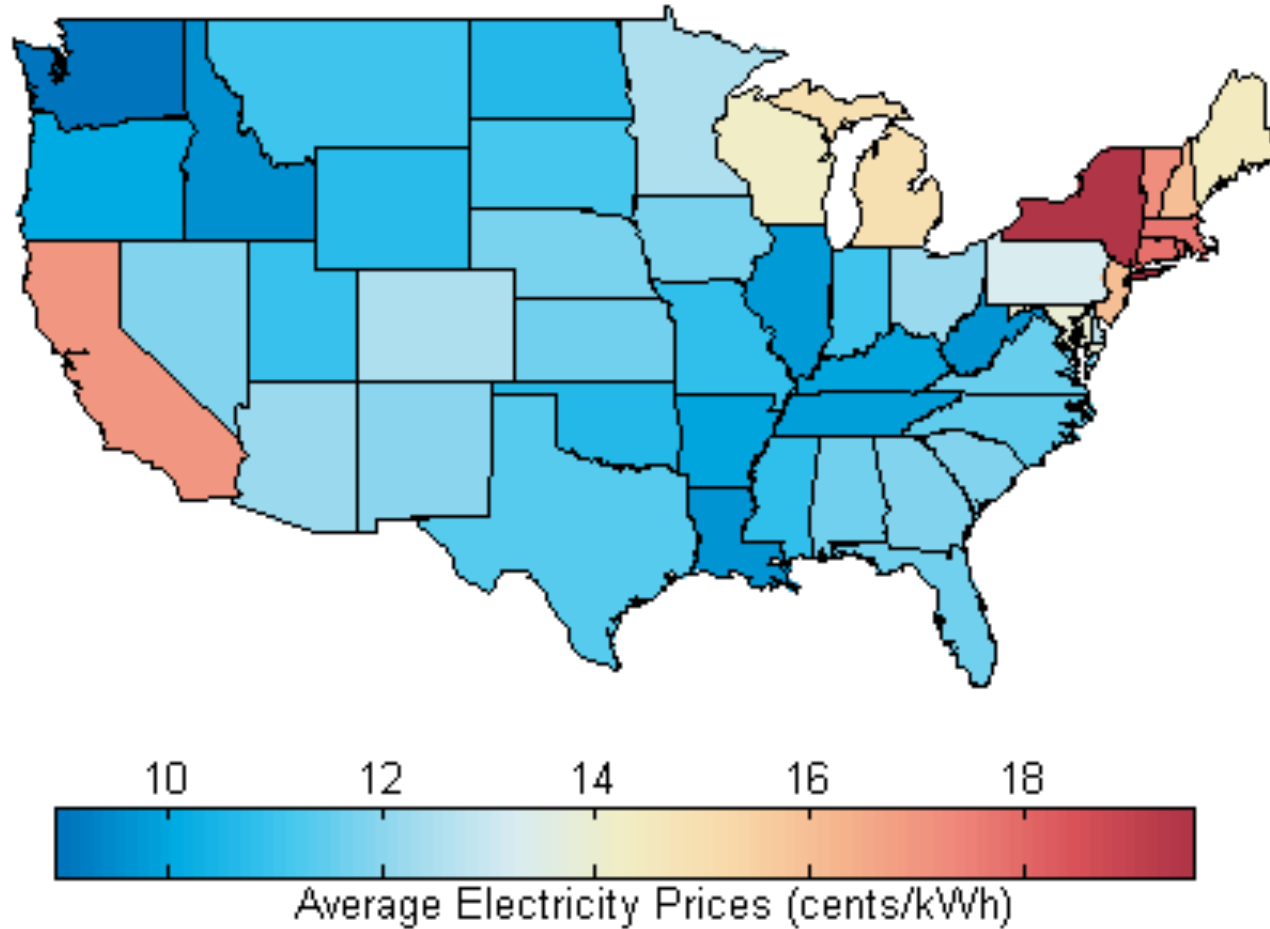
Region	20 th Percentile	Median
Northeast	4.3	5.1
Mid-Atlantic	4.4	4.7
Southeast	4.6	5.6
Midwest	4.6	5.8
Southwest	3.9	4.6
Northwest	4.5	5.1
Texas	3.5	3.9
California	4.8	5.7
Hawaii*	4.6	5.6
Alaska*	4.6	5.6

Values based on NREL PV Pricing Trends 2013

* Information not available. Applied average range for 2-5kW systems.



Residential Electricity Price (Sept 2013 State Averages)



Based on EIA Electric Power Monthly

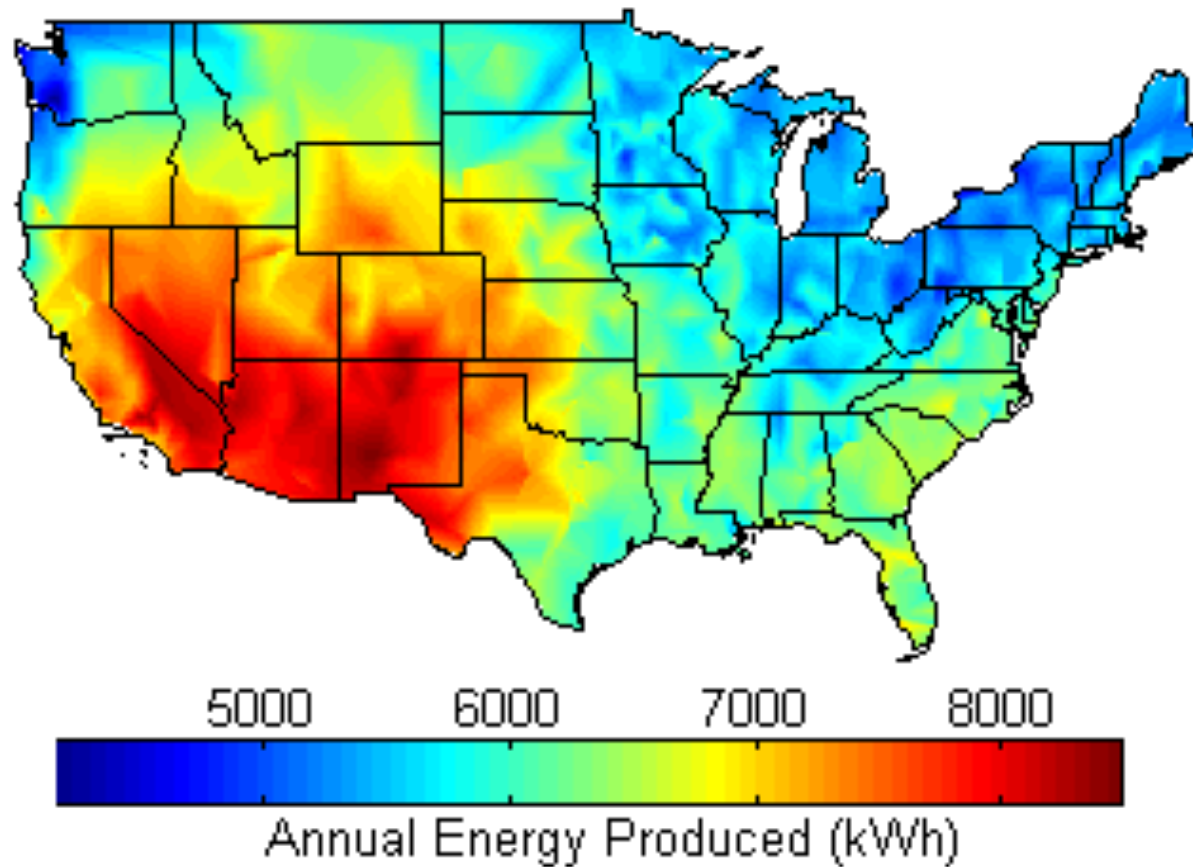


Modeling Power Production

- Use Sandia PV Performance Model
 - Sun-Earth geometry
 - Solar insolation
 - Module performance characteristics
- U.S. weather data from 1,011 stations
 - Typical meteorological year (TMY)
 - Locations across all 50 states



Solar Output for 4 kW System



The annual energy output for a residential solar PV system in Hawaii, not shown, is 6,800 kWh.



Scenarios for Evaluating NPV

Variable	Pessimistic Estimate	Best Estimate	Optimistic Estimate
Installation Cost (\$/W)	Median Values	20 th Percentile	20 th Percentile
Loan Interest Rate	8%	7%	5%
Loan Term (years)	15	20	25
Electricity Price Escalation Rate	2%	3%	5%



NPV Results: Pessimistic Estimate

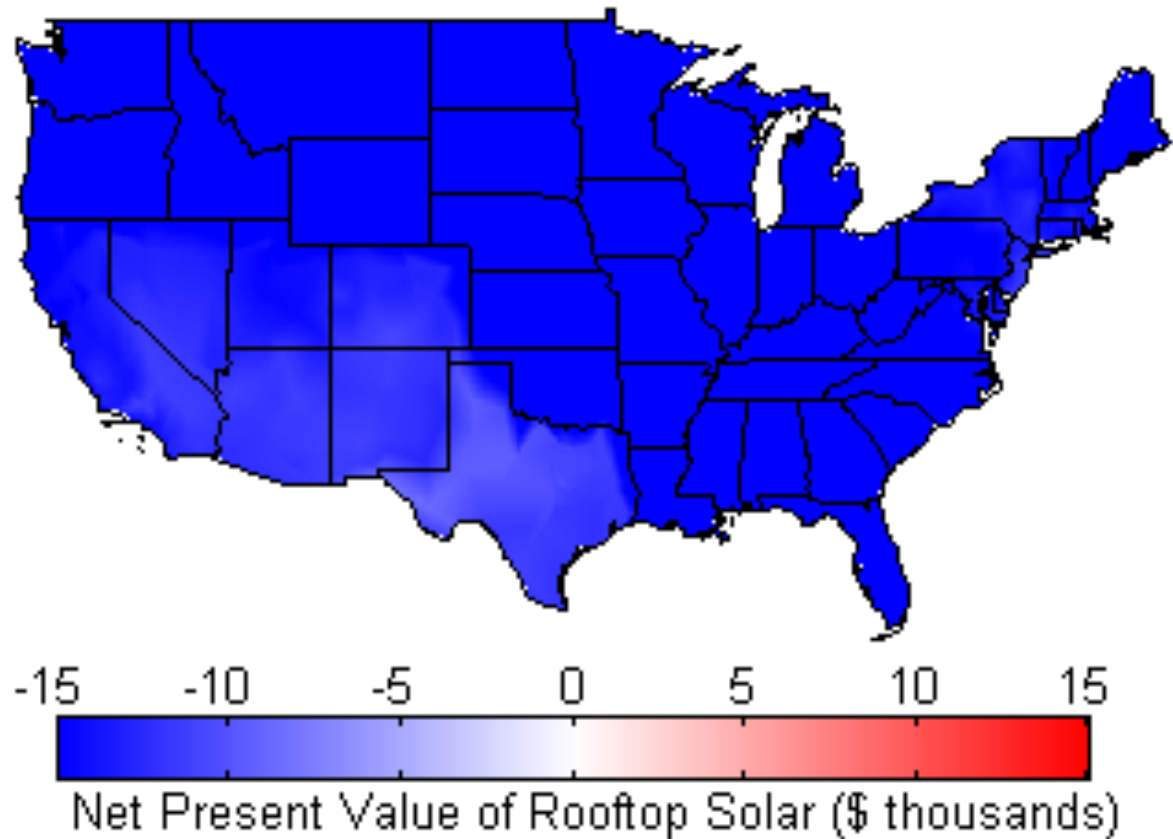
Features:

Median installation costs

Electricity Price ER = 2%

Loan Interest Rate = 8%

Loan Term = 15 years





NPV Results: Optimistic Estimate

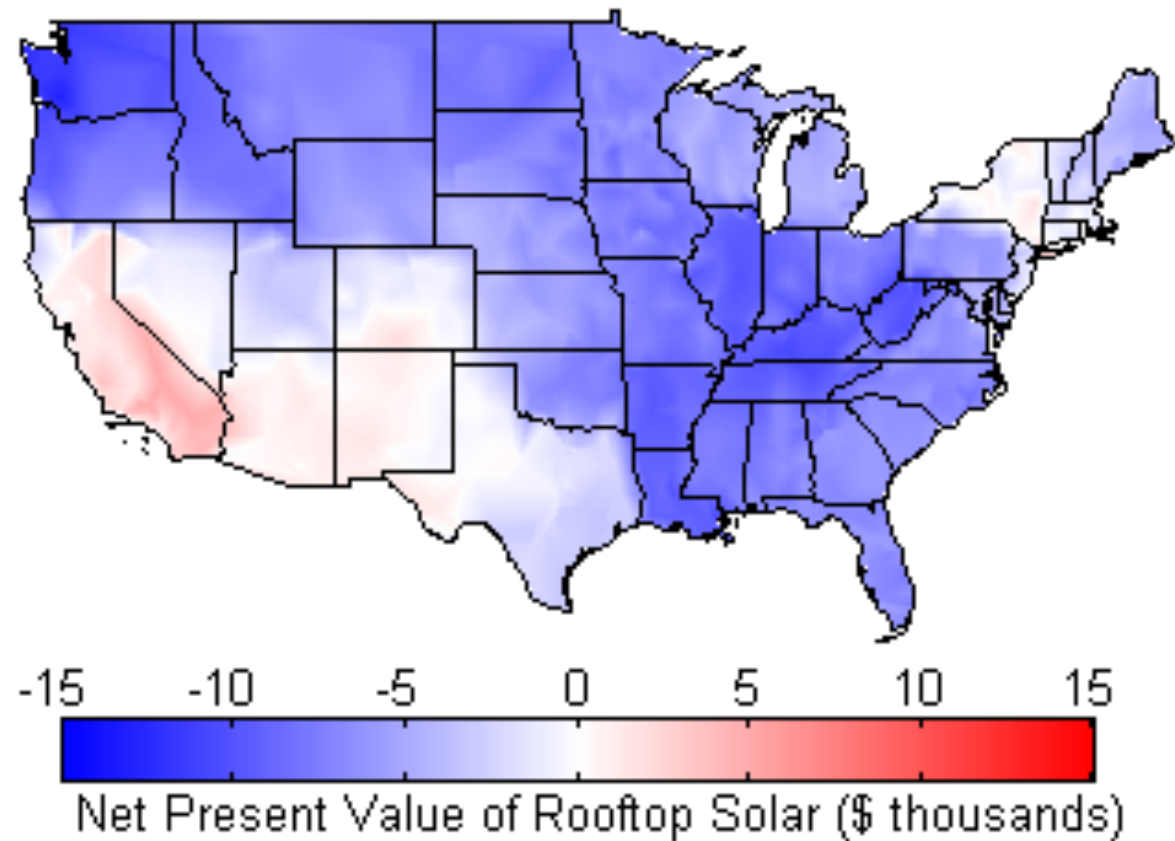
Features:

20th Percentile installation costs

Electricity Price ER = 5%

Loan Interest Rate = 5%

Loan Term = 25 years





NPV Results: Best Estimate

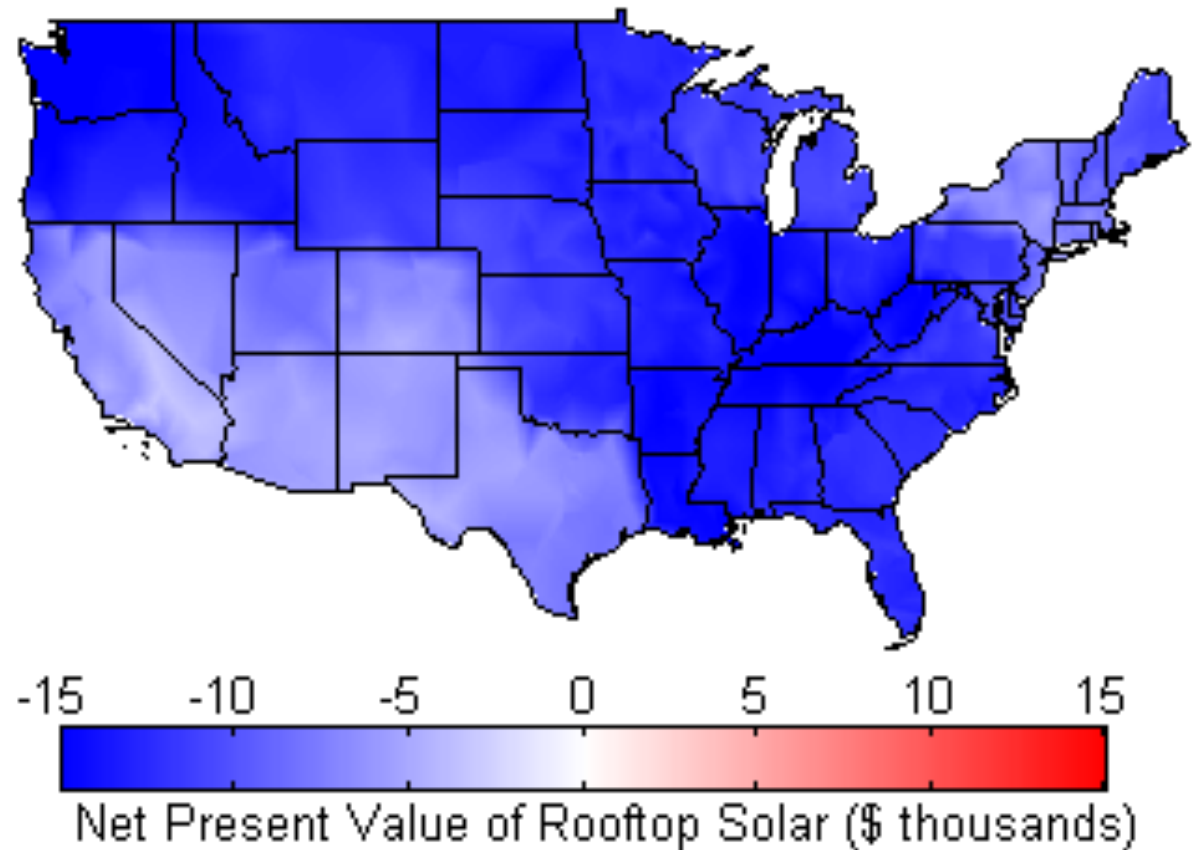
Features:

20th Percentile installation costs

Electricity Price ER = 3%

Loan Interest Rate = 7%

Loan Term = 20 years





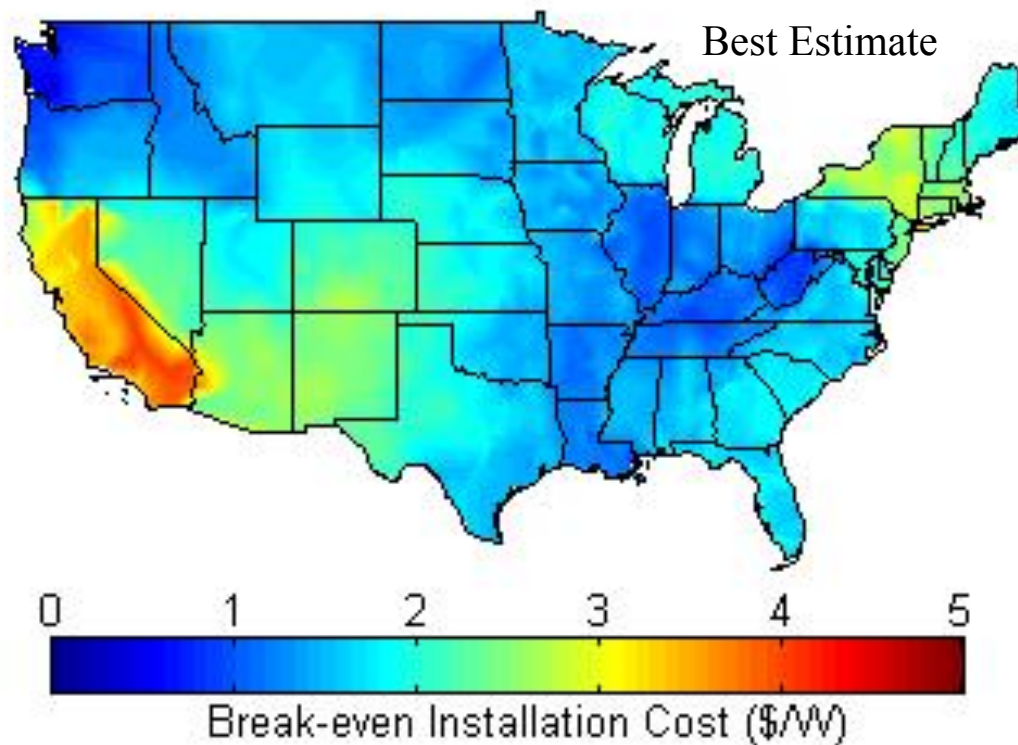
Sensitivity Analysis

Variable	Pessimistic Limit	Optimistic Limit
Installation Cost (\$/W)	Median (1)	80% of 20 th Percentile (1)
Loan Interest Rate	8% (1)	0% (9)
Loan Term (years)	5 (1)	30 (1)
Electricity Price Rate	2% (1)	7% (4)
Discount Rate	0% (1)	10% (1)
Starting Electricity Price	Wholesale (0)	2013 Retail (1)



Break-Even Analysis

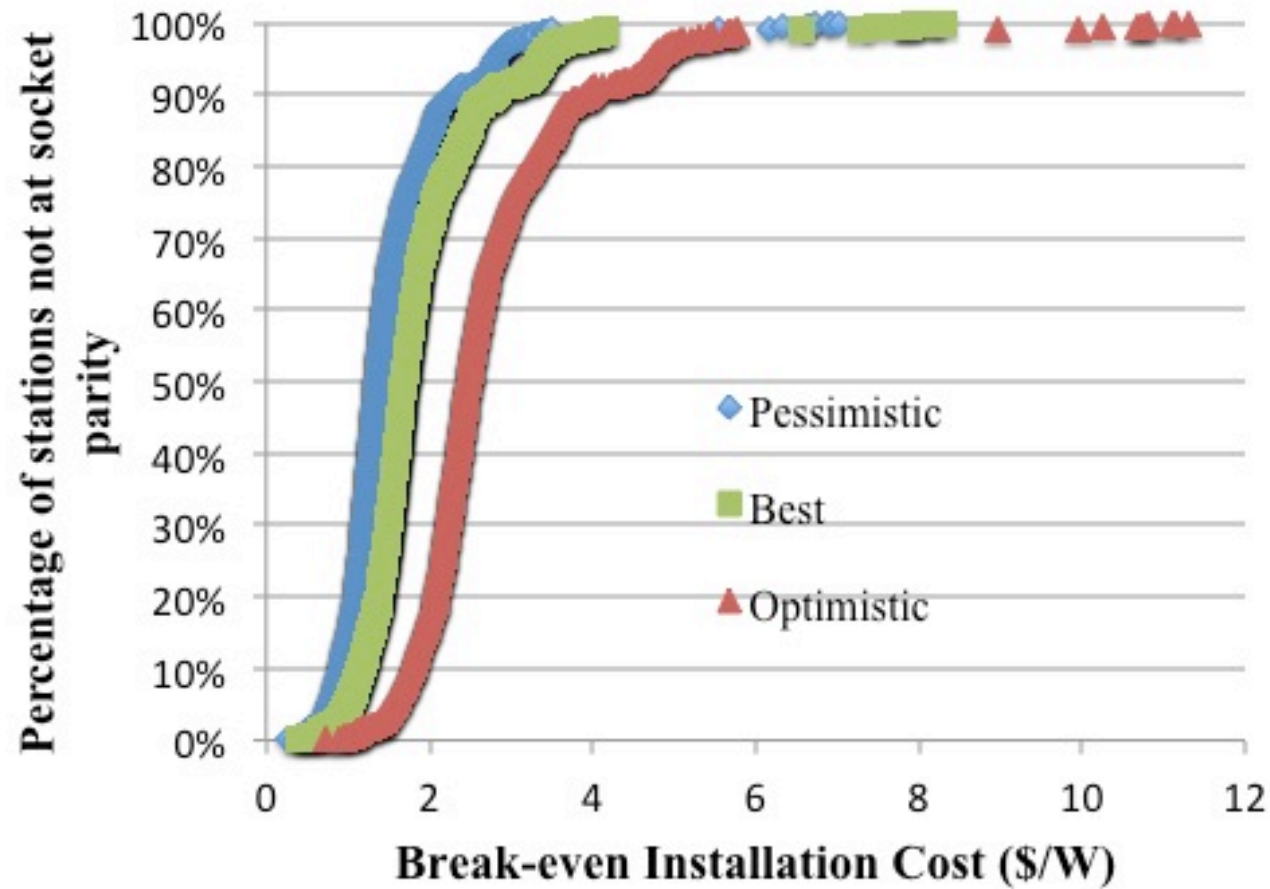
- At what installation cost would the solar PV system break even based on current residential electricity prices?



The average national installation cost is \$4.6/W

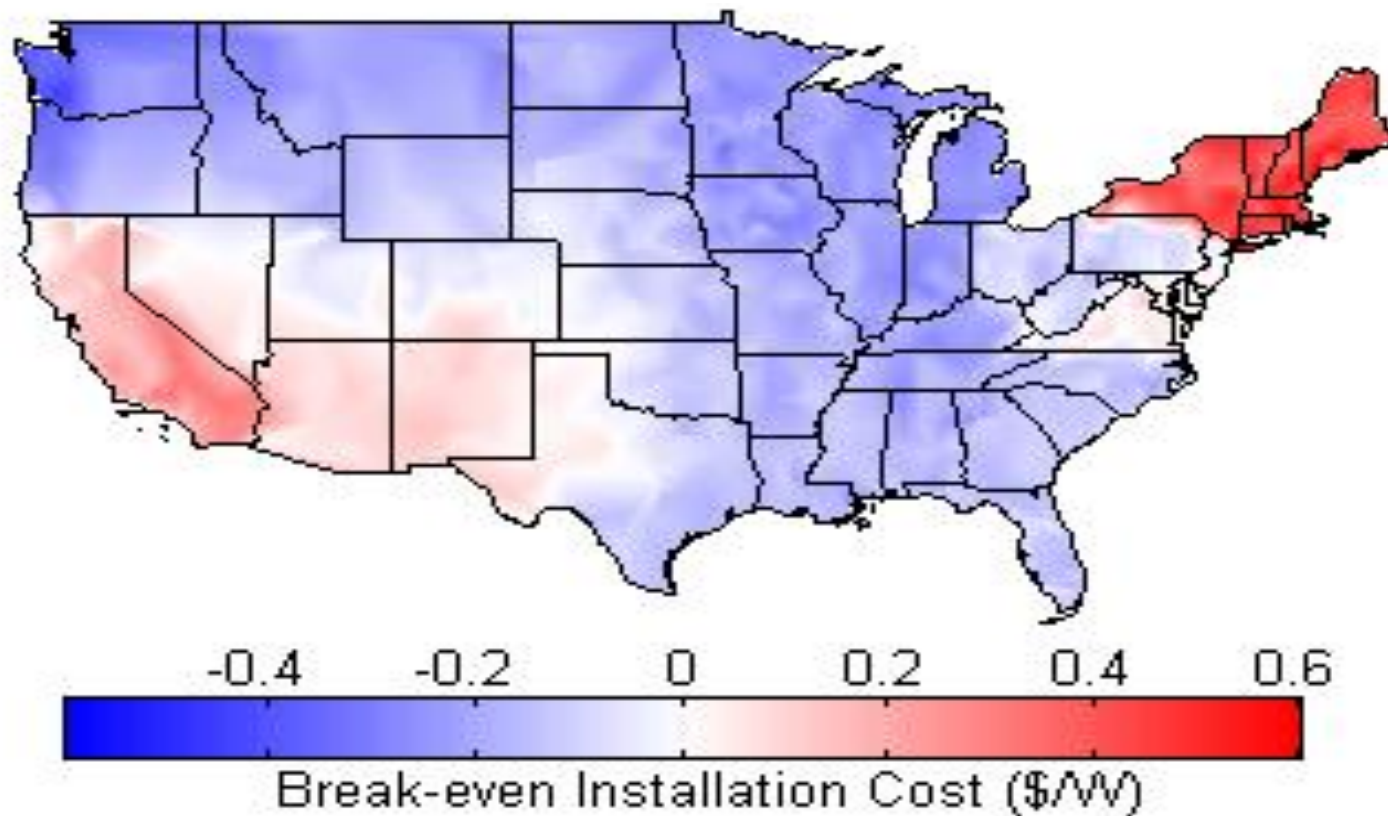


Break-Even Analysis





Break-even Installation Cost with Wholesale Electricity Prices



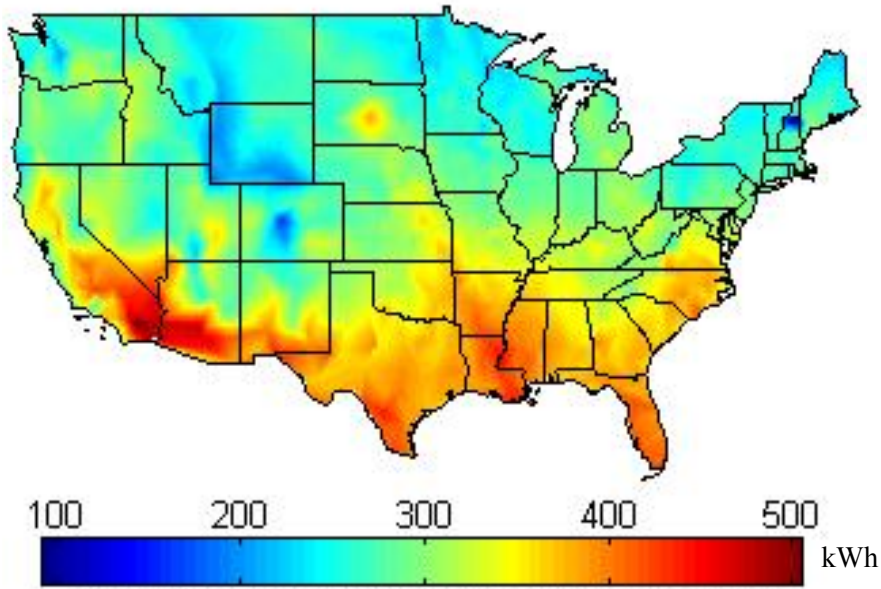


Other module types

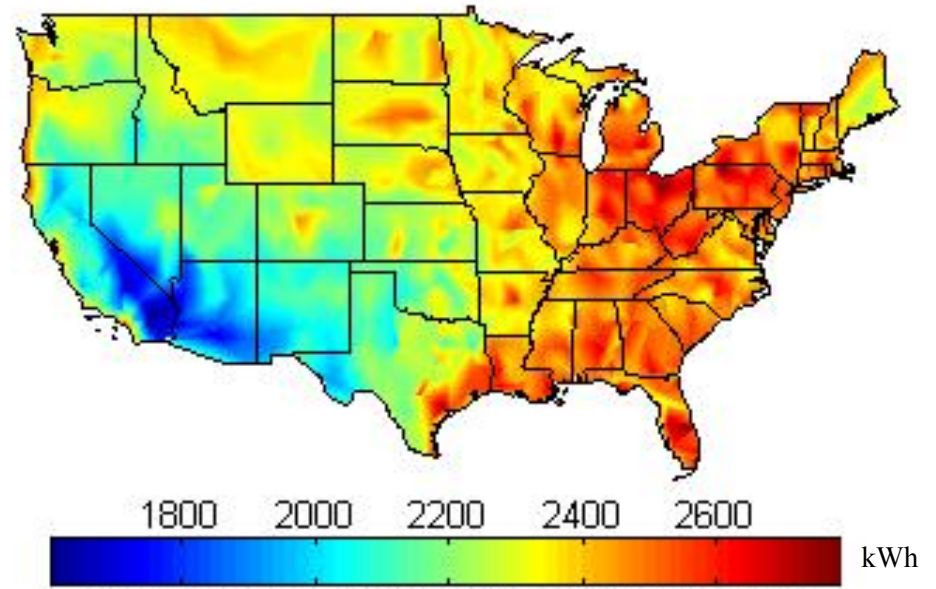
- Other module types are available, though they are not as developed as c-SI.
- These modules have different output patterns, though they all currently produce less power than c-SI.
- Since they are less developed, there may be more room for technological innovation.
- We compared the breakeven installation costs for these technologies.



Difference in Power Output Compared to c-SI



Si-Film

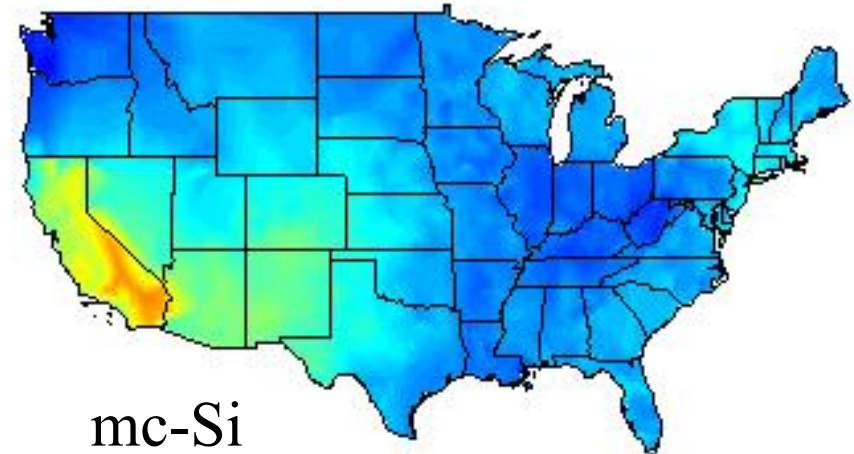
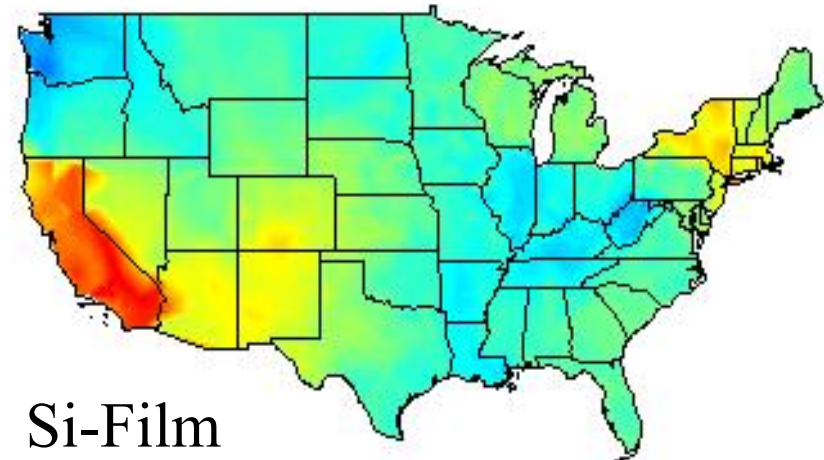
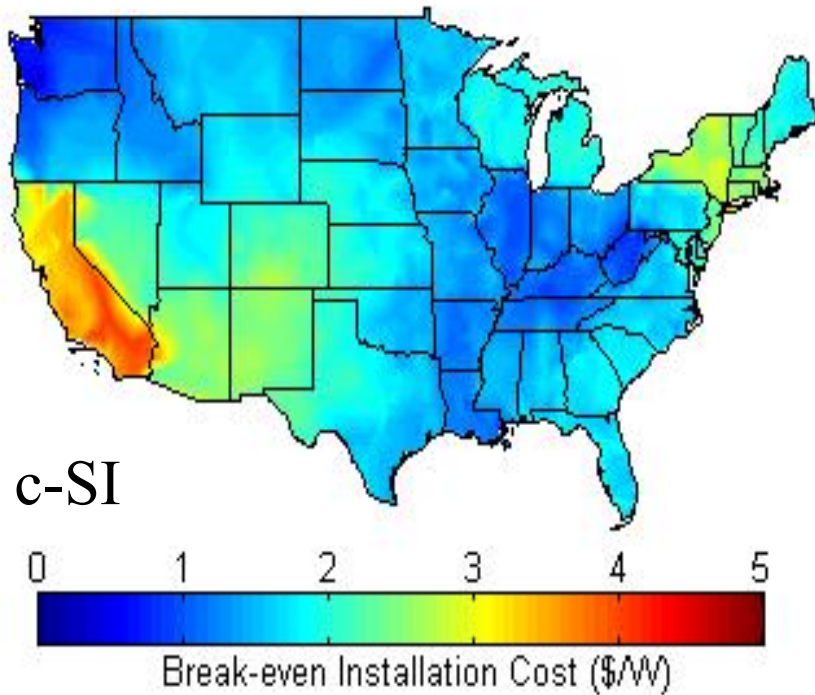


mc-Si

Positive values indicate that c-Si produces more electricity.



Break-even Cost Comparison





Summary

- These results suggest that residential solar PV is still not at “socket” parity in most of the U.S.
- When using current residential electricity prices, installation costs need to be \$2-\$3 per Watt for residential PV to be at “socket” parity without subsidies.
- If we used wholesale electricity prices instead of residential electricity prices, installation costs would need to be less than \$1 per Watt for residential PV to break even.



Conclusions

- Continued government support is still needed so consumers do not “lose” money when they install solar PV on their residences.
- The amount of support needed differs across states. Places like California and New York that are somewhat close to socket parity receive the same federal subsidy as states like Washington and Pennsylvania that are far from reaching socket parity. If direct subsidies on installation costs are to be maintained, it may be worth adjusting the level of support depending on the characteristics of the state.
- The balance of system (BOS) and “soft costs” hold significant potential for reducing the total installed cost.



Conclusions

- While advanced/novel PV technologies underperform m-SI, these technologies may still have more room for technological improvement and cost reductions.
- The characteristics of the power output of these modules may differ throughout the country and be better suited to the operations of the grid.



Future Work

- What is the social value of residential PV?
- What are the costs imposed on the power system as a result of the variability of residential PV?
- How long will it take for residential solar PV to reach socket parity?
- What is the future of net-metering?
- What about cross-subsidization?



Acknowledgements

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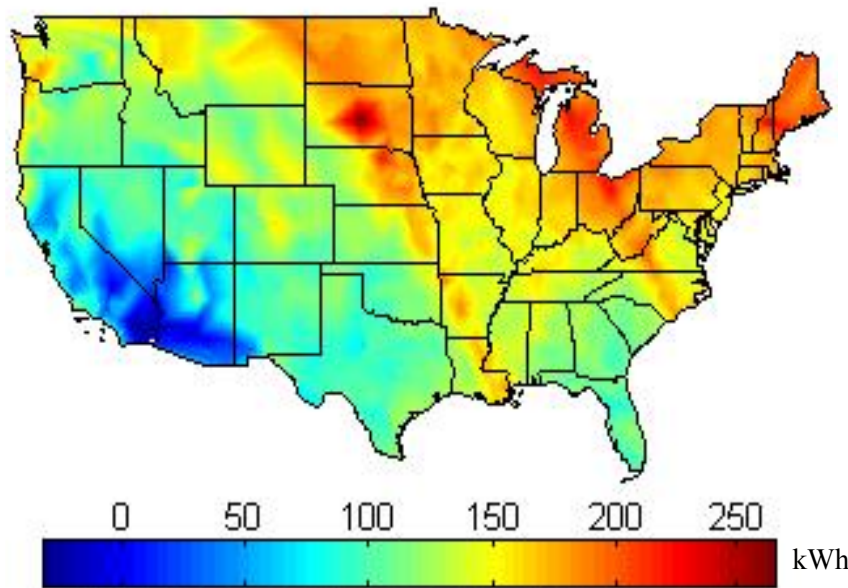
Thank you for your attention

For more information about our work visit our website at:
www.andrew.cmu.edu/users/pjaramil

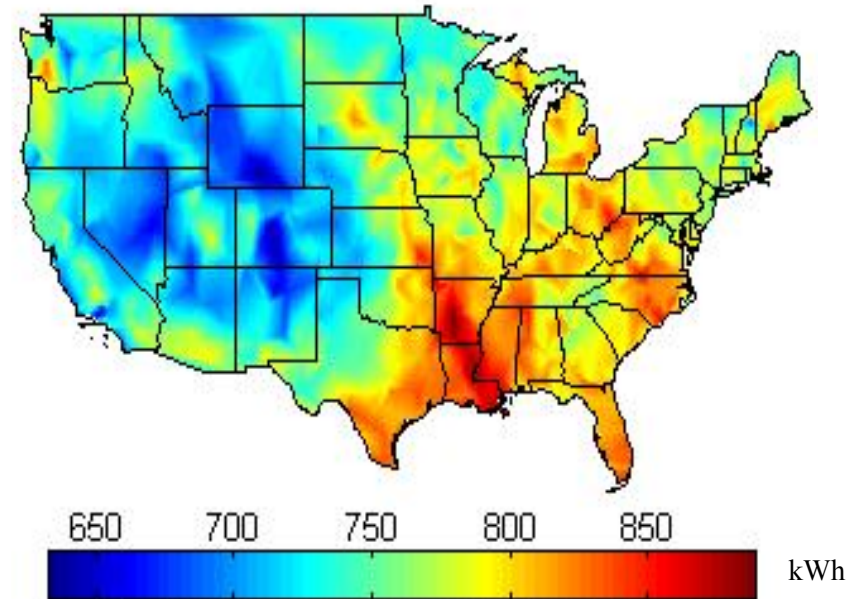
You can also contact me at **paulina@cmu.edu**



Difference in Power Output Compared to c-Si



HIT-Si

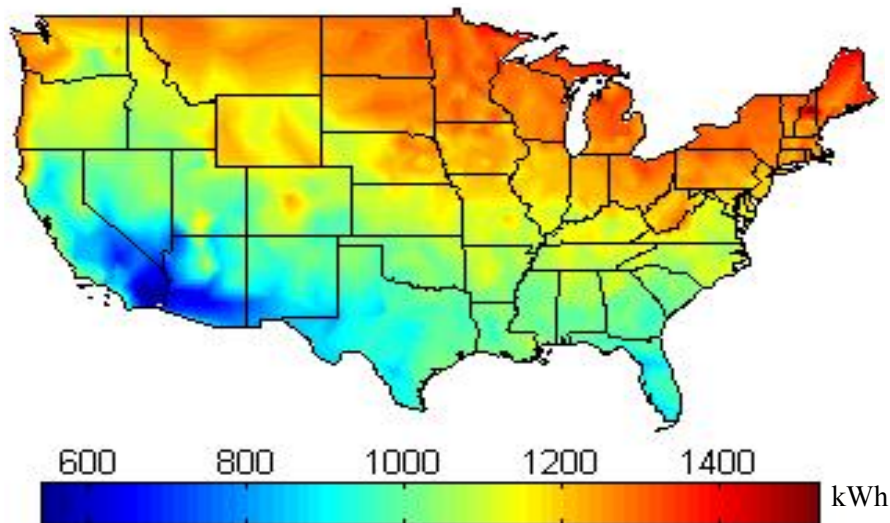


EFG mc-Si

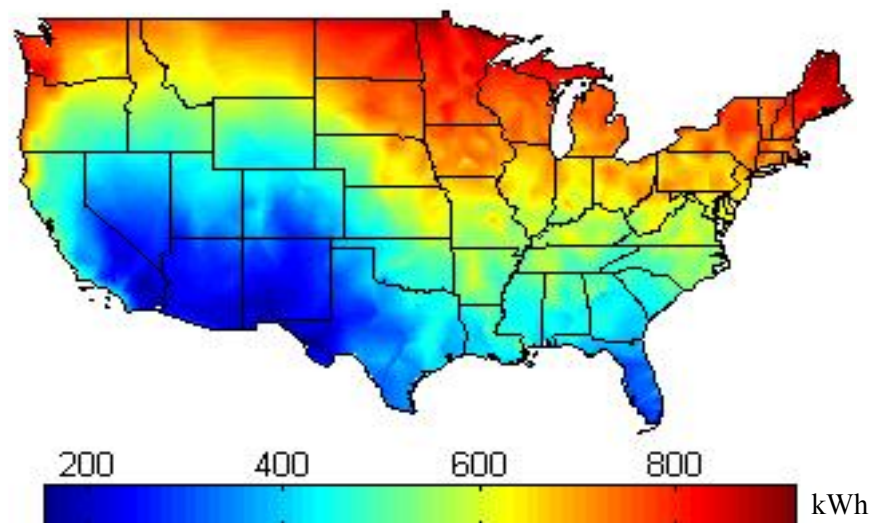
Positive values indicate that c-Si produces more electricity.



Difference in Power Output Compared to c-Si



CdTe

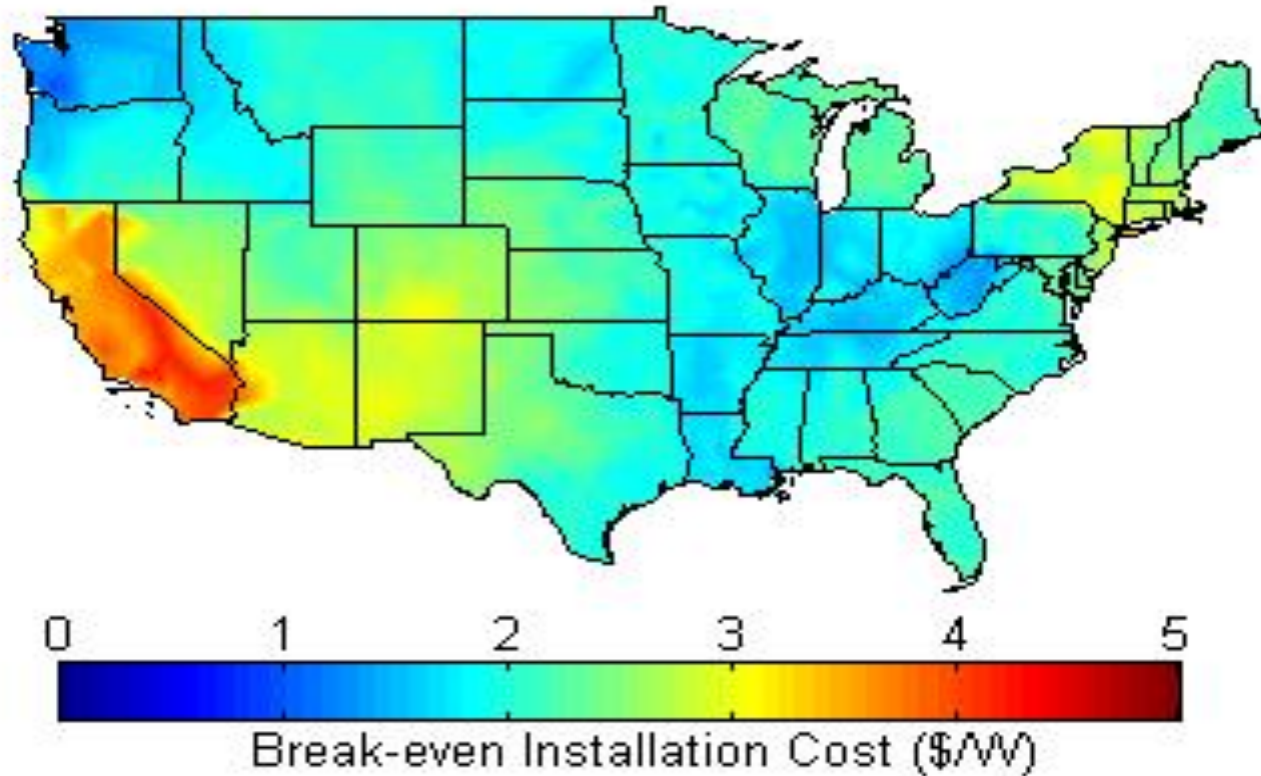


3-a-Si

Positive values indicate that c-Si produces more electricity.



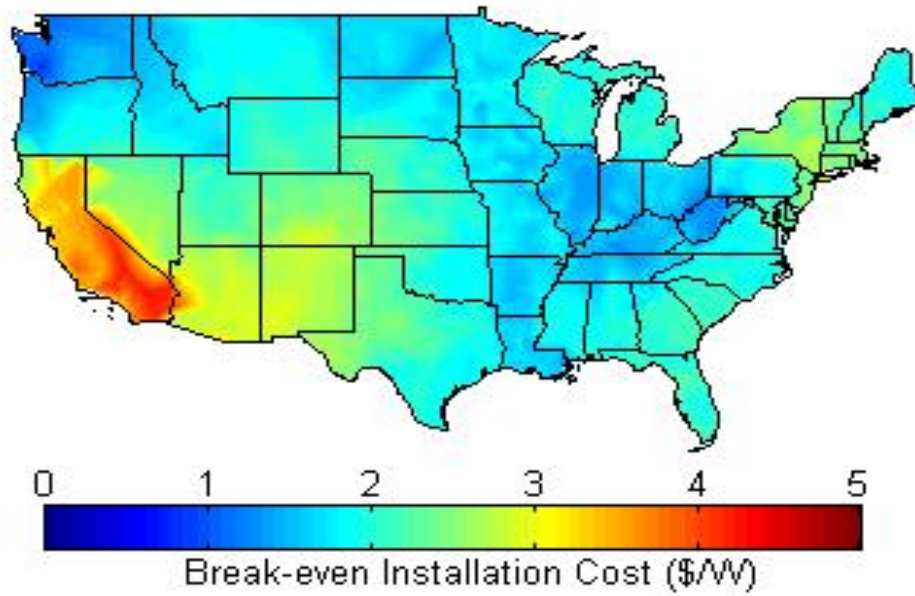
Breakeven Cost



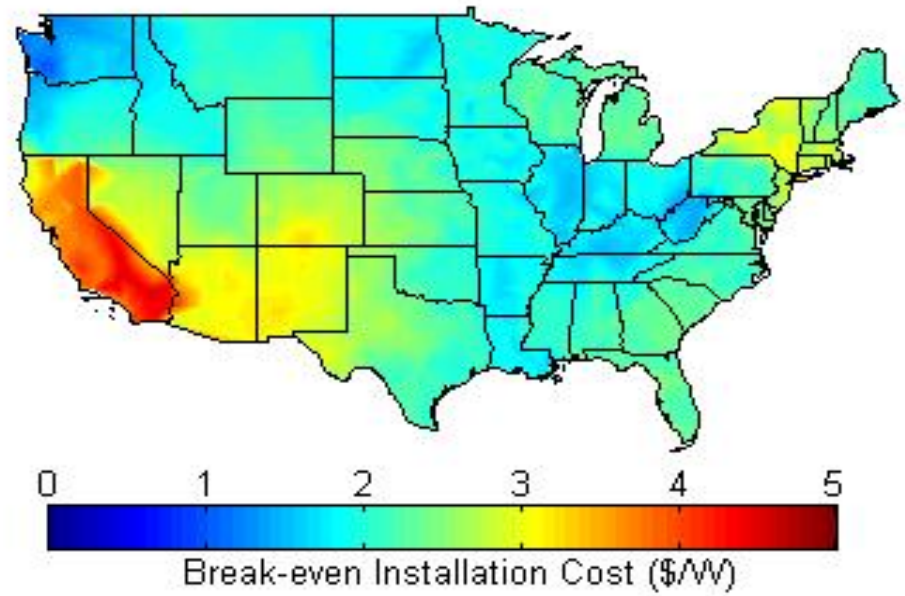
EFG mc-Si



Break-even Cost



CdTe



3-a-Si